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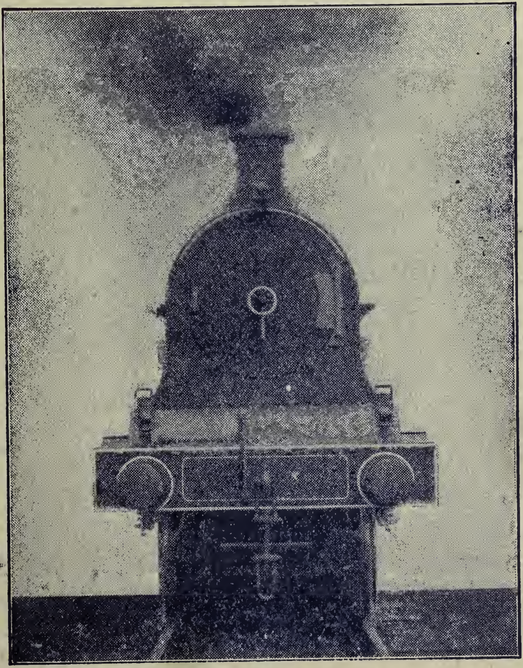

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PREFACE

The feelings of admiration which most of us experience at the sight of a modern express train speeding along at the rate of fifty miles an hour or more, are centred as a rule in the locomotive from which the whole swiftly moving body derives its motion.

To many the sight has but a momentary interest which vanishes as soon as the train is lost to view, whilst on others the effect is to awaken in their minds a desire to know more about the construction of the engine and the principles which govern its working.

Many people, too, have acquired a rudimentary knowledge of the various parts of the engine, and have a rough idea of the functions which certain of these parts have to perform; others, again, are fairly well acquainted with the principal features which distinguish one type of locomotive from another, but are yet at a loss to understand why these differences exist.

It is with a view to clearing away some of the difficulties which beset the path of the seeker after information that this little treatise has been prepared; but, as will be readily understood, the available space

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at disposal will not permit of more than a brief explanation of the principal features of modern locomotive construction and practice. Nevertheless, if as a result of what has been written the student's task is rendered easier, the object sought by the writer will have been attained.

Foreign practice in locomotive construction is not touched upon in this treatise.

C. S. L.

London, E.C.

THE LOCOMOTIVE SIMPLY EXPLAINED

By CHAS. S. LAKE.

CHAPTER I

The Boiler

It is within the knowledge of all that the motive power employed for propelling the vast majority of railway locomotives is steam, and our present aim is to study, firstly, the methods by which the steam is produced; and secondly, the manner in which it is made to perform its work.

In the first place, therefore, let us turn our attention to the boiler as the direct source from which all the necessary power is derived. An example of modern boiler construction is shown on page 9, and by referring to this illustration the method of generating steam may be easily followed.

The fire box is formed of two distinct portions, known as the "inner fire box" and the "outer fire box" or shell. Both are built up of plates riveted together; those used for the inner box being usually of copper, and the outer ones either of iron or steel.

The outer shell is directly connected to the barrel (viz., the cylindrical portion) of the boiler, by means of a riveted joint, but the inner fire box is a separate receptacle altogether, and is connected to the outer shell by means of screwed stay-bolts at the sides, front and back, and also by what are termed roof or crown stays, or bars of various patterns, at the top.

These roof stays generally take the form of girders arranged longitudinally and connected to the outer fire box shell by means of brackets and bolts, or "sling stays," as they are called. On the under side of the girder a number of "lugs" are provided resting upon the top of the inner fire box. The girder is held tightly in position by means of set-screws, entered from the under side of the fire box roof, and screwed into the lugs. In the type of fire box known as the "Belpaire" pattern, which is being largely adopted in this country, the top of the outer shell, instead of being semicircular as in other designs, is flat, like the roof of the inner fire box, and "direct" stays in the form of bolts are used. To those who are unacquainted with these matters the foregoing description, simple as it is, may appear to be somewhat complex, but if the illustrations figs. 1 to 5 are examined, the method of construction will be easy to follow.

A foundation ring is provided as shown, and this forms the bottom of the water space between the

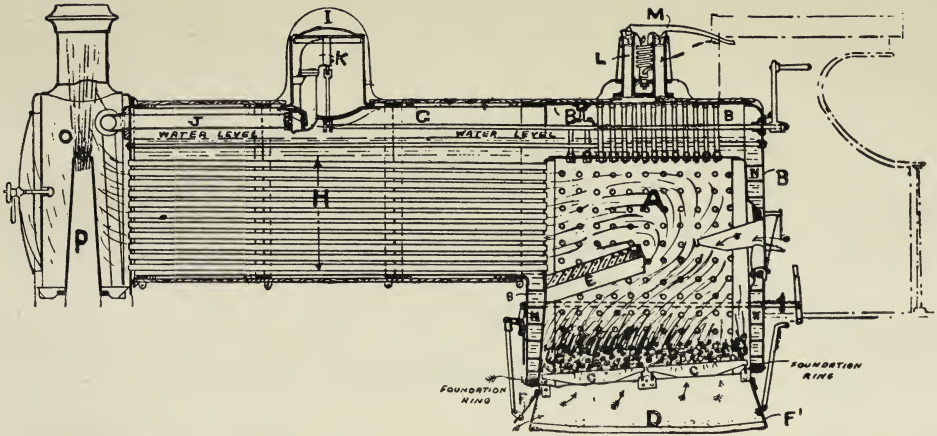


Fig. 1.—Longitudinal Section through a Locomotive Boiler, showing course of Air and Gases.

A	Inner Fire Box	F′	Back Damper (closed).	L	Safety Valve Columns.
B	Outer Shell.	G	Boiler Barrel.	M	,, ,, Lever.
C	Fire Grate.	H	Tubes.	N	Water Space.
D	Ash-pan.	I	Dome.	O	Smoke Box.
E	Brick Arch.	J	Steam Pipe.	P	Blast Pipe.
F	Front Damper (open).	K	Regulator.		

inner and outer fire boxes, the plates of which are riveted together through the foundation ring, and also round the fire hole, which, as its name implies, is the opening through which the coal is shovelled when the fire is being replenished.

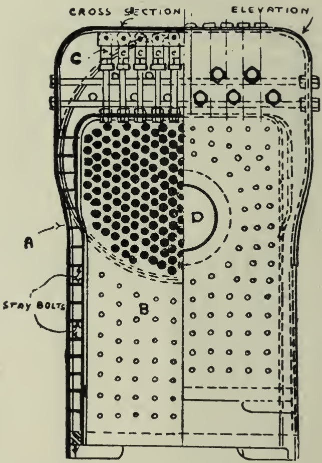


Fig. 2.—Belpaire Fire Box.

A Outer Shell.
B Inner Fire Box.
C Roof or Crown Stays.
D Fire Hole.

Below the fire box is the *fire grate*, which consists of a number of bars arranged longitudinally (see fig. 5), with spaces between them to allow of the passage of air to the fire. Unless this is provided for, the perfect combustion of the fuel could not take place.

Below the grate, again, is the *ash-pan* (fig. 1). This is provided to catch the ashes which fall through between the fire bars, and if the drawing (fig. 1) is referred to, it will be noticed that the ash-pan is fitted with "dampers" both front and back. These consist of flat plates suspended on hinges, and capable of being opened or closed at will by the engine-driver.

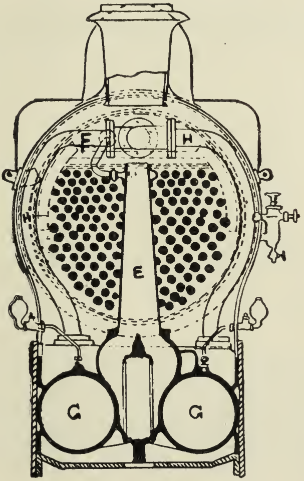


Fig. 3.—Section through Smoke Box.

E Blast Pipe.
F Tube Plate.
G Cylinders.
H Steam Pipes to Cylinders

It is by means of the dampers that air is admitted to the fire grate. Mechanism in the form of an arrangement of rods and levers, and communicating with the driver's "cab," is provided, and the handles for manipulating this gear are formed with a series of notches upon them, so that the amount of opening of the dampers may be varied and the current of air regulated, according to the requirements of the fire and the circumstances under which the engine is

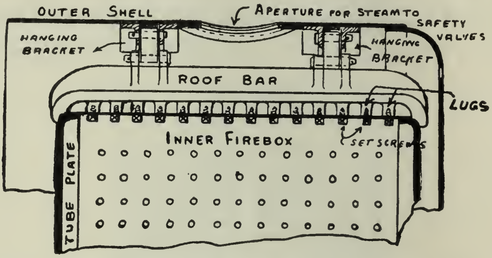


Fig. 4.—Fire Box Roof Bars—Girder Pattern.

working at any given time. Another important feature of fire box construction is the *brick arch* (figs. 1 and 5). The function of this is to deflect the gases

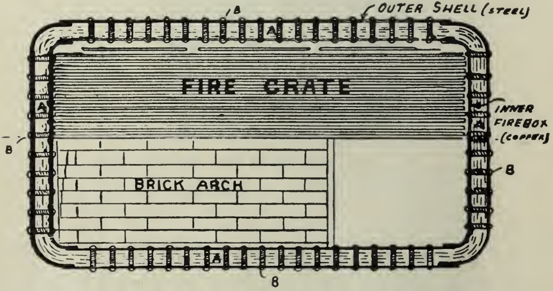
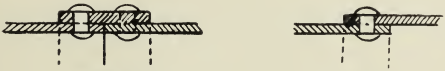


Fig. 5.—Sectional Plan of Locomotive Fire Box.

(Upper half shows fire bars in position, the lower half with them removed.)

A Water Space. B Screwed Stays (copper).

arising from the fire, over towards the back of the fire box, and by so doing to retard their progress towards the tubes, thus causing them to circulate more generally about the fire box, and so to ensure their more thorough combustion before entering the tubes. The barrel of the boiler is built up of iron or steel plates in the form of rings riveted together. Some boilers are of the "telescopic" pattern, others are parallel throughout. The telescopic boiler is produced by forming the rings of different diameters and then overlapping the ends and riveting all round the overlapped portions. The rings of the parallel boiler are of the same diameter throughout, and are connected by what are termed *butt joints*; one form of which, as well as a specimen of lap jointing for telescopic pattern boilers, is shown in fig. 6.



Butt Joint. **Lap Joint.**

Fig. 6.—METHODS OF CONNECTING BOILER PLATES.

The boiler barrel contains a large number of tubes which extend the entire distance between the firebox "tube plate" at the one end and the smoke box tube plate at the other. These plates contain a number of holes corresponding to that of the tubes, and the ends of the latter are passed through these holes and are then expanded in the plate by means of a special tool known as a "tube expander," a process which makes them a tight fit in the tube plate. At the fire box end the tubes are beaded over after passing through the plate, and steel ferrules are in most cases driven in. This is done to protect the ends of the tubes from damage arising from the action of the fire.

The front tube plate separates the boiler barrel from the smoke box, whilst the back tube plate is an integral part of the inner fire box. The tubes are made either of copper, brass, iron or steel, and are usually between 200 and 250 in number according to their size.

The hot gases arising from the fire have to pass through the tubes on their way to the smoke box, and in so doing they transmit the greater part of the heat which they contain to the tubes, which are quickly heated through, and as the water in the boiler is in direct contact with the outer surfaces of the tubes, it rapidly becomes converted into steam. The water also surrounds the inner fire box except on the under side. The space between the inner and outer fire boxes, and which is spanned by the screwed stay-bolts already referred to, is called the "water space," and here steam is very quickly produced owing to the much greater heat given off by the fire box as compared with the tubes, on account of the plates, of which the former is comprised, being directly exposed to the intense heat of the fire and the flames and gases whilst at their highest temperatures. The inner surfaces of the tubes and the walls of the interior fire box (that is to say, the parts with which the gases, etc., are brought directly in contact) are termed the *heating surfaces* of the boiler. Every locomotive engineer recognises the necessity of providing as much heating surface as possible in the engines he designs, for upon the steam-raising capabilities of the boiler the success of the locomotive very largely depends.

The majority of modern locomotive boilers are supplied with a steam dome. The function of this appendix is to form a reservoir for the collection of steam well up above the water-level of the boiler. It is a well established fact in engineering, that more work can be got out of an engine when "dry" steam (*i.e.* steam with which water is not commingled) can be obtained, and consequently by taking it at a point as far removed from the boiler barrel as is practicable, the risk of water being intermixed with the steam is minimised, although by no means entirely obviated. The regulator valve which governs the admission of steam to the cylinders, is located in the dome for the reasons referred to. A pipe, sometimes termed the dry steam pipe, extends from the dome to the smoke box, where the supply pipes to the cylinders are connected up to it. These supply pipes encircle the inside of the smoke box, in which the temperature is always very great, so that in this way the steam is subjected to a drying influence immediately before reaching the cylinders.

Some engineers fit a device known as a "superheater" to their engines. This apparatus, as its name indicates, is provided for raising the temperature of the steam and thus ridding it of moisture, or "saturation," as it is called, before being used in the cylinders.

Those engines which are not provided with domes are fitted instead with a "steam collecting pipe" running along close to the inside of the top of the barrel above the water-level. The upper portion of this pipe is perforated with a number of holes through which steam enters. In such cases the regulator is in the smoke box.

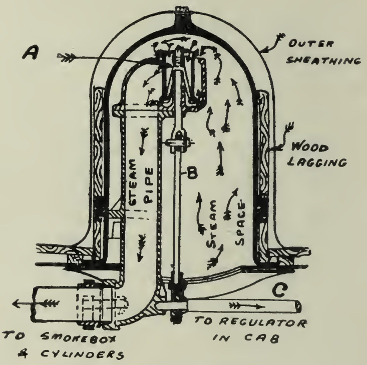


Fig. 7.—Steam Dome.

(Arrows indicate passage of steam.)

A very popular type of regulator valve for use in the dome is shown in fig. 7. The valve itself (A) is cylindrical in form, and has top and bottom seatings. When lifted off these seatings by means of the rod B (which is raised and lowered by means of an eccentric worked from the cab by rod C) steam enters at the top (as indicated by arrows), and also passses through the body of the valve and enters the pipe from the under as well as the upper side of the valve. This is a very simple type of regulator, and is extensively used on some railways.

The safety-valves on most locomotives are placed over the fire box except where domeless boilers are used, when they are more often than not mounted upon the middle ring of the boiler barrel. The most popular type of safety-valve in this country is that known as the "Ramsbottom" pattern, which consists of two hollow pillars or columns open to the boiler at their base and closed at the tops by the valves themselves, which, as will be seen, are united by a lever and held down on their seats by means of a spring.

These valves are "loaded" to resist all pressures up to that at which it is desired that the steam should "blow off"; or, in other words, that at which it shall have acquired sufficient force to lift them off their seats, and by so doing clear a way for its own escape.

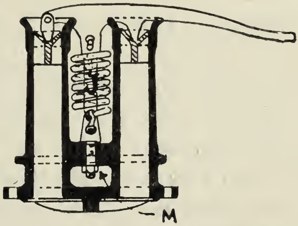


Fig. 8.—Ramsbottom's Duplex Safety Valve.

The loading process is effected by adding tension to the spring J (fig. 8) until the desired amount has been reached. Assuming for the moment that the pressure selected is 175 lb., then sufficient tension must be put upon the spring to keep the valves down on their seats until the needle of the pressure gauge in the driver's cab points to that particular figure, when the force exerted by the spring is overcome by the pressure of the steam acting upon the valves, with the result that they are lifted from their seats and the steam escapes into the atmosphere. To adjust the valves to any required pressure it is necessary to screw up the nut M (fig. 8) (while the boiler is under steam) until the correct degree of tension to withstand pressure up to that determined upon is arrived at. The steam pressure of modern first-class British locomotives ranges between 175 and 200 lb. per sq. in.

The boiler barrel, the top and sides of the outer fire box, and the dome, are covered with material of a non-conducting nature such as wood, felt, or asbestos, to prevent loss of heat by radiation. Of the three substances named, wood is by far the most commonly used. This covering is termed the "lagging" of the boiler, and outside this again comes the iron sheathing, which is formed of plates held in position by means of bands or hoops (also of iron), the ends of which are brought together below the boiler and pulled up tight with a small bolt and nut.

It is this outer sheathing which is visible to the eye in the completed engine, and which is painted and lined out in the attractive manner common in this country.

The smoke box is the chamber situated at the forward end of the boiler, and in it are the pipes which supply steam to the cylinders, the blast pipe which provides a means of escape for the steam after it has done its work in the cylinder (the exhaust steam, as it is called), the blower (one form of which is illustrated by fig. 9 and described later), and other minor appurtenances according to the designer's individual practice.

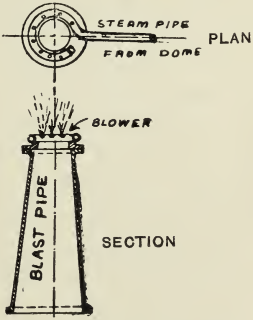


Fig. 9.—Blast Pipe and Blower.

Some engineers provide their engines with "spark arresters," and these when present are invariably placed in the smoke box. The chimney, which is either built up of wrought iron plate, or constructed of cast iron in one piece, may be of various patterns, each railway having virtually a design of its own, although some resemble others so closely that it would be difficult to distinguish them if removed from their respective engines. The orifice of the blast pipe is arranged to come immediately beneath the opening of the chimney, so that the exhaust steam may have free means of escape to the atmosphere outside. It will be noticed that on some, in fact on the majority, of recent engines the chimneys are very short. The necessity for providing boilers of greater steam-raising capacity has led to larger diameter barrels being used. This fact has compelled designers to pitch the boiler with its axis higher above the rails than usual, so that the larger diameter of the barrel may clear the wheels; and as no engine in this country may stand at a greater height than 13 ft.

6 in. above the rail (that dimension being the "British loading gauge" measurement), the increased height of the boiler has made it compulsory to cut down the length of the chimney. On some locomotives an extension piece, virtually a continuation of the chimney itself, is carried down into the smoke box, with a view to creating a better draught. It is the practice also on some railways to use extended smoke boxes. The principal object aimed at in this construction is to provide a larger space for the collection of ashes which find their way through the tubes in company with the gases from the furnace. The effect of the blast on the fire is less acute with the extended form of smoke box, and consequently the ejection of ashes into the atmosphere, commingled with the escaping steam, is considerably lessened. When very narrow smoke boxes are used, "fire throwing," or sparking, is often very noticeable indeed. This will be better understood after reading Chapter II., in which the action of the exhaust steam and its effect on the fire is explained.

The door of the smoke box is circular in form, and is dished out with a view to strengthening it. It is suspended on hinges, and a handle is provided in the centre of the door for opening it, and a second handle is used for screwing it tightly up to the front of the smoke box. The spindle carrying these handles has a spade-shaped head with shoulders, and this head is made flat so that it may easily pass between two bars stretched across the smoke box inside. By turning the handle outside, the head is brought into a vertical position with the shoulders bearing against the bars (after having passed between them flatwise), so that it is impossible for the door to be opened unless the handle is turned again to bring the spade end into its flat position once more, and then it can be withdrawn between the bars again and the door opened.

The object of the door is principally that of providing a means of access to the tubes and for facilitating operations when washing out the boiler.

Before leaving the subject of the smoke box, a few explanatory remarks on the construction and object of the *blower* may be of service. One form of blower is illustrated by fig. 9. It is formed by bending a small pipe into the shape of a ring, which encircles the mouth of the blast pipe. In this ring a number of small holes are provided, and the pipe, of which the ring is part, is led away to the dome from whence it obtains steam. By manipulating a handle in the cab the driver can admit steam to the perforated ring, and this steam, by escaping through the holes and up the chimney, exercises a similar effect upon the fire as does the exhaust steam from the cylinders when the engine is running, only of course in a much lesser degree. The blower is principally used when the engine is stationary, and especially just before starting away from a terminus, when it is necessary that the fire should be aroused a little.

The cab, which provides shelter for the enginemen, is placed at the fire box end of the boiler. The design of the cab is a matter which rests entirely with the designer of the engine. Some cabs are

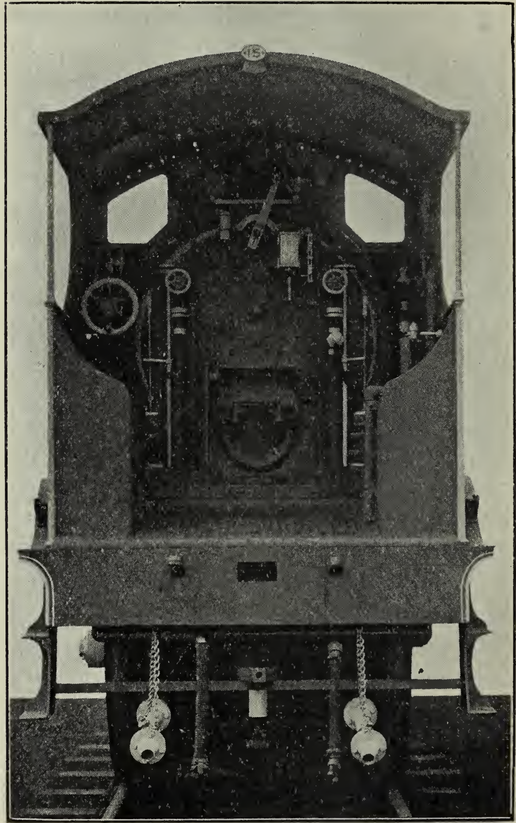


Fig. 10.—Arrangement of Driver's Cab, "Precursor" class Engines, London and North-Western Railway.

commodious and well arranged, others are precisely the opposite. The writer speaks after a lengthy experience of both, and can testify to the advantages possessed by the more ample designs.

The cab fittings having direct relation to the boiler are the water-gauge columns, for indicating the height of water in the boiler, the pressure gauge for showing the steam pressure therein, injectors for supplying the boiler with water, and last, but not least, the regulator handle or "starting lever," by means of which the driver controls the movements of the engine.

CHAPTER II

THE ENGINE

HAVING gained some idea of the method by which steam is generated, it now behoves us to follow its action in propelling the engine. The broad principle of the steam engine is probably understood by the majority of readers, and there is really no material difference between that principle as applied to locomotives and to other types of engines. For the benefit of those whose ideas are not clear upon the subject, however, the manner in which motion is communicated may be briefly explained. In the preceding chapter we found that the steam for supplying the cylinders was taken either from the dome or collected by means of a perforated pipe. In either case its actual admission into the cylinders is effected in the same manner, viz., by means of slide valves.

Those readers who have studied the action of that important member (which subject has already been dealt with in a very concise manner by another writer, in a work forming one of the same series as the present little work[1]) will be well acquainted with the mode of distributing steam to the cylinders, and for the moment this feature will be passed over. The steam having been admitted to the cylinder, pushes the piston therein before it. Attached to the piston is a rod, the opposite end of which is secured to a *cross-head*, which is virtually a block sliding between two bars termed “guide” or “slide” bars. Affixed to the cross-head again is a *connecting rod* which communicates rotary motion to the driving wheels, through the medium of what are termed cranks. Reference to the diagram fig. 11 will serve to demonstrate simply the manner in which the reciprocating movement of the piston and cross-head is transformed into a rotary one at the crank axle.

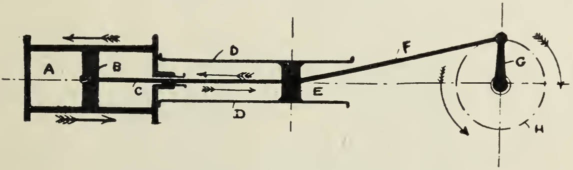


Fig. 11.—Diagram of Engine Parts.

(Movement may take place in either direction shown by arrows.)

A Cylinder.
B Piston.
C Piston Rod.
D Slide Bars.
E Crosshead.
F Connecting Rod.
G Crank.
H Path of Crank Pin.

The majority of locomotives are provided with two cylinders. These may be placed either between or outside the main frames of the engine. When the former plan is adopted, the engine is described as having "inside" cylinders, whilst with the other arrangement it is spoken of as being an "outside cylinder engine."

---

[1] “The Slide Valve Simply Explained.” By W. J. Tennant, A.I.Mech.E., Model Engineer Series No. 2.

The use of inside cylinders renders it necessary to construct the axle of the driving wheels with two cranks in it, as it is impossible to arrange for the connecting rods to actuate crank pins attached to the wheels themselves, as is done when the cylinders are outside the frames.

The cranks are set at an angle of 90° to one another (right angles), so that when one of the pistons is at the end of its stroke the other is exerting full power.

Those engines which have more than one pair of wheels of the same diameter as the driving pair, have such wheels connected together by means of rods, the object of which is explained in Chapter III. We may now perhaps revert to the subject of the cylinders, and study briefly the action of the steam within them, and this brings us again to the subject of the valves and the manner in which they work.

These valves are of various patterns, but the most common is that known as the "ordinary flat or D pattern slide valve." This consists of what we may term a rectangular block with a cavity on its under side. This block is made to slide to and fro over the face of the ports in the valve chest, which latter chamber is usually cast in one with the cylinders in modern practice. This movement of the valve over the face of the ports has the effect of alternately opening and closing them to admit a fresh supply of steam and to allow the exhaust steam to escape.

A form of valve known as the "piston" or cylindrical type is largely used by some engineers. The construction of this valve may be followed by referring to fig. 12. The idea is to lessen as much as possible the resistance due to friction caused by the constant rubbing of one surface against another. In the piston valve there are no large surfaces exposed to steam, and it is more easily moved than the ordinary slide valve; and as its frictional area is so much less than that of the last-named pattern, the loss of power due to that cause is largely minimised.

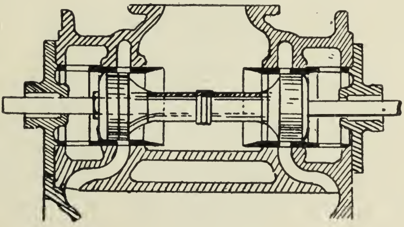


Fig. 12.—A Locomotive Piston Valve.

The mechanism by means of which motion is imparted to the valves is termed the *valve gear.* To adequately deal with this branch of our subject a very large amount of space would be required. The pattern of gear most extensively used in this country is that known as the "Stephenson" or "shifting link motion," and is illustrated by fig. 13.

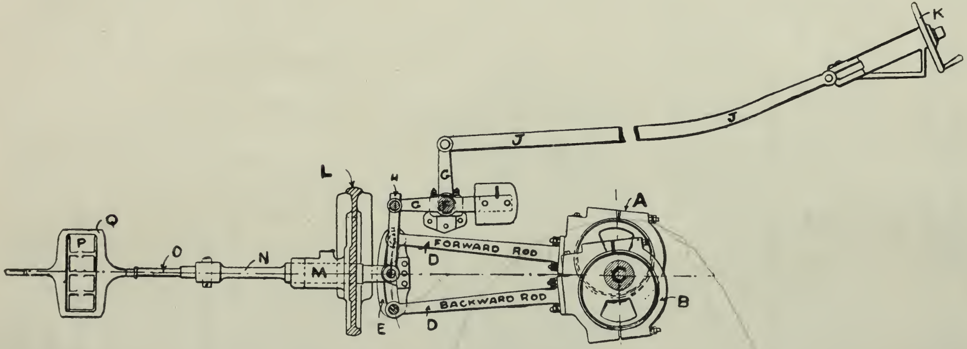


Fig. 13.—STEPHENSON'S LINK MOTION
(in mid-gear position).

A Forward Eccentric.
B Backward ,,
C Crank Axle (in section).
D Eccentric Rods.
E Expansion Link.
F Weigh bar Shaft (in section).
G Bell Crank.
H Suspension Links.
I Counterweight.
J Reversing Lever.
K Reversing Wheel (in cab).
L Motion Plate.
M Spindle Guide.
N Valve Spindle.
O Valve Rod.
P Slide Valve.
Q Slide Valve Buckle.

Briefly, this consists of four eccentrics keyed to the axle of the driving wheels. These eccentrics are virtually cranks whose throw must be equal to half the travel of the valve. There are two sets of gear to the engine, and we will confine ourselves to dealing with one set, taken by itself. Thus we have two eccentrics, one of which is called the *forward* eccentric and controls the forward movement of the valve, and the other is known as the *backward* eccentric, which similarly governs the backward movement of the valve. The centre portions of the eccentrics are called the sheaves, and the other portions the straps. Attached to the straps are rods known as the forward eccentric rod and the backward ditto. These rods are forked at their forward extremities, and these forked ends are secured to a curved link termed the *expansion link*, the forward eccentric rod being attached to the top of the link, and the backward rod to the bottom thereof. The link is supported by others known as the suspension links, which are attached to a shaft above carrying a weighted bell crank, the upper arm of which communicates, by means of a rod, with the reversing handle or wheel in the cab. The expansion link can be either raised or lowered, and the process of so doing effects the reversing of the engine, and also governs the amount of travel given to the valve, and thus varies the periods of admission and expansion of steam in the cylinders. The rod which connects the slide valve with the link is made in two portions. The first portion is secured at one end to the valve, and at the other to the second spindle, whilst the rearmost end of the latter is forked and encloses both the link and also a block which fits in the slot of the link. This block is fixed to the valve spindle, and is stationary so far as *vertical* movement is concerned.

Now we know already that the link may be raised or lowered as desired, and it may also be held in any position in relation to the valve spindle as follows:—If the link is lowered as far as possible, it will have the effect of bringing the *forward* eccentric rod somewhere near in line with the valve spindle, and this will cause the valve to be under the direct influence of the go-ahead eccentric; and whilst the link is in this position, if steam is given to the engine it will move forward. This position is known as *full forward gear.* In a similar manner, if the link is *raised* to the utmost extent, the backward rod and the valve spindle are then nearer being in line, and the backward eccentric exercises the greater influence, and the engine will be reversed and travel in the opposite direction. This will be full backward gear. Now place the engine in *mid gear*, viz., with the link located centrally (*i.e.* with its top and bottom extremities equidistant from the centre of the valve spindle). Open the regulator with the link in this position. The engine will not move. Why? Because the valve is now equally influenced by both eccentrics, each counteracting the action of the other, and minimising the travel of the valve to such an extent as to render it impossible to get sufficient steam into the cylinders to operate the pistons.

Any position of the link may be used *between full and mid gear* on either side of the centre of the valve rod, and the engine will run either backwards or forwards according to which end of the link is nearer to the centre of the spindle.

By means of this arrangement the travel of the valve can be suited to almost any circumstance. It can be varied so that the cut-off is early or late, and in this way a great economy in steam is effected.

Readers have doubtless observed that when an engine is starting away from a station, especially when it has a load behind it, the sound of the exhaust is very loud and sharp. After a short period has elapsed, however, this sound is considerably modified. Why is this? It is because the engine has got the train "in hand" and well on the move, and can now afford to work with a smaller supply of steam, and the driver knowing this has "linked up" accordingly; that is to say, he has raised or lowered the link (according to whether he is running in forward or backward gear) from full position to some intermediate point between that and mid gear, and so has reduced the travel of the valve; is thereby cutting off earlier, with a longer period of expansion in the cylinder, and is consequently economising steam, saving coal, and increasing his "bonus" all at the same time.

Now a word or two about *lap*, which has a great deal to do with cut-off in the cylinder. Lap is the amount that the valve projects beyond the port opening when the valve is in its *central position*, and it will be understood if this is read with sketches before one that the greater amount of lap, the earlier will be the cut-off, and the longer will the steam be imprisoned in the cylinder, during which time it will be working *expansively*. With a late cut-off, such as where the valve has no lap (or when the engine is working in full gear the steam would have to be continuously supplied and exhausted and no expansion would take place, and this would do away with all the economical working methods which the expansion link and lap provide. By *lead* is meant the width of port opening when the piston is at the beginning of its stroke. The valve closes the exhaust port at that end of the cylinder which the piston is approaching *before* the piston reaches the end of its stroke, and the steam left in the cylinder acts as a cushion against the advancing piston as it nears the end of its stroke. This is done to prevent shock and undue stress on the other parts of the motion. Then the valve admits a little live steam, and this lends impetus to the piston and gets it ready to start on the return stroke the instant the crank is over the dead centre.

The action of the steam of the cylinder, and the movements of the valve, may be briefly summed up as follows:—

(1) Steam admitted to cylinder, termed *admission*.

(2) Valve closes admission port, termed *cut-off*.

(3) Steam shut in cylinder works expansively, termed *expansion period*.

(4) Valve opens exhaust port, termed *release.*

Now what takes place after release? The exhaust steam escapes by way of the blast-pipe and the chimney into the atmosphere. In so doing it drives the air before it up the chimney, thus creating a partial vacuum in the smoke box, which has to be compensated for by air entering through the damper and fire hole, and thence *via* the tubes to the smoke box.

The effect of the blast, therefore, is to create a draught, and by so doing to cause the fire to burn more rapidly, and it goes without saying that the greater the volume of steam and the quicker the succession of exhaust discharges, the more fiercely will the fire burn. The blower, it will be remembered, replaces this action of the blast-pipe when the engine is stationary.

Another pattern of valve gear which is largely employed in Great Britain is that known as the "Joy" gear, after the name of its inventor.

In this type no eccentrics are employed, motion being taken direct from the connecting rod of the engine (see fig. 14).

The absence of the eccentrics renders the use of this gear possible and advantageous where it would be extremely difficult, if not impossible, to fit that already described. In cases where locomotives have three or more cylinders driving separate pairs of wheels, such as the three cylinder engines on the L. and N.-W. Railway, and the four-cylinder design on the L. and S.-W. Railway, Joy's gear is employed for the outside cylinders, as it occupies much less space and is in every way more convenient under the special circumstances involved. Many of the North-Western engines have their driving axles supported in the centre by an additional bearing carried by a frame between the crank webs, and this occupies the space usually taken up by the eccentrics, so that to fit the Stephenson link motion in this case the central bearing would have to be abandoned, whereas its presence in no way interferes with the working of the Joy gear. Space prevents a detailed account being given of the working of the gear; full descriptions of which may be found in all the principal books which are published on the "Steam Engine."

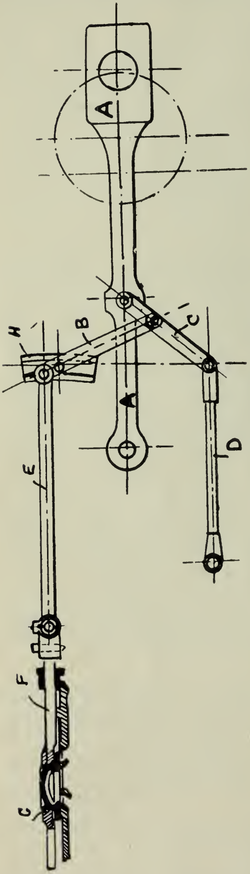


Fig. 14.—Joy's Valve Gear.

A Connecting Rod of Engine.
B Valve Lever.
C Correcting Link.
D Radius Link.
E Valve Rod.
F Valve Spindle.
G Valve (working above cylinder).
H Curved Slide.

Briefly, the desired movement of the valve is brought about by utilising independently the backward and forward movement of the connecting rod and combining this with the vibrating movement of the rod, and the result is a movement which is suitable to work the valves, allowing of the use of any proportions of lap and lead required, and giving an almost mathematically correct cut-off for both sides of the piston, and for all intermediate degrees of expansion. All these terms will be familiar to the student by now if he has read the description of the link motion which precedes this, and he will know within a little what it is that is required of a valve gear.

The operations of reversing the engine and varying the valve travel are effected by altering the position of the curved slide block H. By inclining it *forward* of the vertical the engine is made to move forward, whilst by inclining it *backward* of the vertical the engine will move backward. The central position corresponds to mid-gear.

The various movements of the curved slide are controlled from the cab by means of the reversing wheel and rod.

The reader's attention having been called to the subject of steam economy as effected by cutting off the supply to the cylinder before the piston has completed its stroke, the moment is opportune in which to say a few words on that vastly important branch of the same subject, viz., *compound locomotives.* This term is probably a familiar one to many, but precisely what it is that constitutes the term may not be equally apparent. In a compound locomotive the cylinders are of unequal diameters. There may be only two cylinders, or there may be more, but in any case there is always a difference in their sizes. Speaking for the moment of a two-cylinder compound, the smaller one will be termed the *high-pressure* cylinder and the larger one the *low-pressure* cylinder. Steam from the boiler is admitted in the ordinary way to the former, and after it has done its work therein it passes into the low-pressure cylinder instead of being discharged straight away up the chimney as usual. The work performed in the low-pressure cylinder is wholly due to the steam expanding therein, and so it will be seen that the one supply of steam does its work twice over, and the advocates of the compound principle point to this fact as constituting a great advantage, and claim economy of steam (and consequently fuel) as one resultant gain. In the "simple" engine, as those having non-compound cylinders are called, each supply of steam does its work in one cylinder only, and is ejected into the air whilst still retaining a large percentage of usefulness; and this, it is stated, is thrown away, whereas in the compound engine practically all the power is taken out of the steam before final exhaust takes place. Around the point represented by the relative merits of "compound" *verus* "simple" locomotives a fierce controversy has raged ever since the compound principle was applied in a practical manner to railway engines; and even now, after years of experiment and trial, the adherents of either principle still retain their original opinions. There are three- and four-cylinder compounds, and also three- and four-cylinder simple engines in use in this country, but the multiplication of cylinders in the latter class is a very uncommon-practice, the number being almost universally restricted to two.

A few words as to the construction of the cylinders will be useful before passing on. They are made of cast iron, and, as before stated, are in many cases cast in one with the steam chest (in which the valve works). When *inside* cylinders are used it is customary nowadays to cast the pair of them and the steam chest all in one. With the outside position this is of course impossible, for then the cylinders are separated from one another by the width at which the frames are set apart. Both ends of the cylinder are provided with covers as shown in the drawing, and the back cover carries the *stuffing box*, through which the piston rod has to pass backward and forwards. Inside this box the *packing* is placed to prevent steam from leaking through from the cylinder and thus being wasted.

Sometimes asbestos is used as packing, and at other times " metallic " packing, consisting of a system of metal rings and springs, is employed. A gland (fig. 15) fits into the opening of the stuffing box, and this can be forced against the packing by screwing up the nuts which will also be seen in the drawing. This compresses the packing, and as wear takes place and a disposition to leak (or "blow," to use the correct expression) manifests itself, the nuts are screwed up and the leakage stopped.

The steam chest may be cast either so that the steam and exhaust ports are above, below, or at the side of the cylinder, when the latter is secured in position. This depends mainly upon other circumstances in the design of the engine.

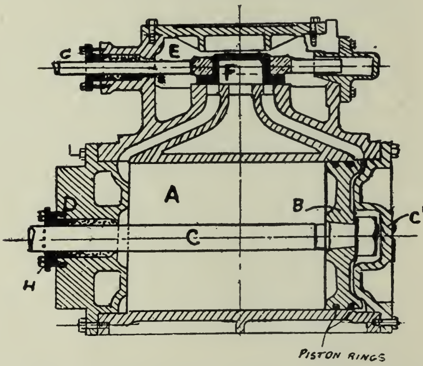


Fig. 15.—SECTION THROUGH CYLINDER AND STEAM CHEST.

A	Cylinder.	E	Steam Chest.
B	Piston.	F	Slide Valve.
C	Piston Rod.	G	Valve Rod.
D	Stuffing Box and Cover.	H	Gland.
C^1	Front Cylinder Cover.		

The piston is a circular disc of metal, made usually of cast iron and slightly smaller than the inside diameter (the *bore*) of the cylinder. Around its outer circumference channels or grooves are cut. Rings or hoops of iron fit into these grooves. These are known as the "piston rings," and they are made so as to be an easy fit with regard to width, and about one eighth inch larger in diameter than the cylinder. They are turned so as to present a smooth outer surface, and a piece about a quarter inch long is then cut out of the ring before placing it in the groove. This imparts a quality of spring to the ring, and when the piston is being placed in the cylinder the rings have to be compressed; but once inside, the tendency is for them to spring outwards, and thus form a steam-tight joint with the smooth bore of the cylinder, and preventing steam working past the piston and being wasted. If the outer surface or face of the piston itself were made to fit in the cylinder and the rings dispensed with, then after a slight amount of wear had taken place the piston would allow steam to pass and would thus have become useless, whereas the rings continue to spring outwards as they wear; and as they are very cheaply produced, it is a very easy and inexpensive matter to replace them. The piston rod passes through the piston and is secured by means of a nut. That portion which rests within the body of the piston is tapered, as is also the hole which receives it, thereby forming a perfectly secure and rigid fastening.

The distance travelled by the piston on the passage from one end of the cylinder to the other is termed the *piston stroke,* and this corresponds exactly with the diameter of the circle described by the centre of the crank pin—the *path* of the crank pin, as it is called. The cylinder must be so fixed that a line drawn through it horizontally intersects the centre of the axle to be driven. If this were not done the rotary motion of the crank would not be possible. Sometimes cylinders are inclined towards the crank axle. Then a line parallel to the angle at which they are set must also pass through the centre of the axle.

The cylinders used on modern locomotives are from 17 up to 20 in. in diameter by 24 or 26 in. stroke. Low-pressure cylinders vary very greatly. On the North-Western Railway they are principally 20½ and 30 in. diameter according to the class of engine. Drain-cocks are fitted at either end of the cylinders for ridding them of water. These cocks are controlled by rods from the cab.

The engine and boiler of a locomotive are carried upon frames supported by wheels and axles. These frames are usually made of steel plates about one inch in thickness. Their outline depends very largely upon the type of engine for which they are intended. Fig. 16 shows one of the frames of a four-wheels coupled express locomotive with a leading four-wheeled "bogie" truck. The guides F and F^1 are bolted to the frame, and they are provided with flanged faces upon which the axle-box may slide up and down according to the effect produced by unevenness of the rails upon the spring. The forward end of the frame is narrow at G and G^1, and deeper again at G^2. The narrow parts are so formed to clear the tops of the bogie truck frames, and the deeper portion is made thus so as to provide a bearing surface to which the cylinder may be bolted.

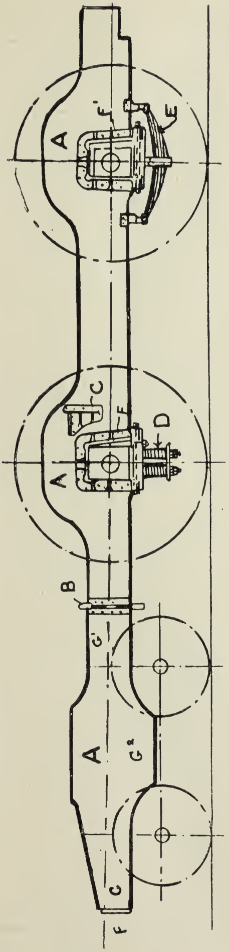


Fig. 16.—The Framing of a Four-coupled, Bogie, Passenger Locomotive.

A Main Frame.
B Motion Plate.
C Cross Stay Plate.
D Coil Spring.
E Laminated Spring.

In engines where the leading truck is absent and a single pair of wheels are provided, the forward end of the frame is differently formed, and then an additional opening is provided for the guide and axle box of the leading axle. This part of the frame has to be made much deeper if it is for a passenger engine, on account of the leading wheel being smaller in diameter than the others; but if a *goods* engine this is not necessary, as all wheels are then of the same diameter (Chapter III.).

The majority of locomotives have two frames, but some have four, viz., two inside the wheels and two outside, but, as stated, it is more usual for the engine to have one frame on either side.

The frames are placed not more than about 4 ft. 1 in. apart (for the standard gauge, *i.e.* 4 ft. 8½ in.), and they are stayed together at different points. The *buffer beam* at F acts as a stay at the extreme end, and when inside cylinders are provided they form an excellent means of holding the frames securely in position. Then there is the *motion plate*, which stretches across from one frame to another, and is bolted to both. This plate supports the after ends of the slide bars and the guides for the valve spindles. A stay-plate is usually provided immediately in front of the fire box, and finally a large cast iron "footplate" is fitted between the frames at the trailing end. The axle boxes are usually formed of gun-metal, and they are allowed a little side play in the guides to facilitate movement when traversing curves.

The wheels of a locomotive are comprised of four parts: viz., the centre (which includes the spokes and rim), the tyre, the axle, and the crank pin. The material used for the centre is either wrought iron, cast iron or cast steel. The tyres are "shrunk" (*i.e.* forced) on to the rim of the wheel whilst hot and by means of hydraulic pressure. After the tyres have been shrunk on, the wheels are taken to the lathe, and there the surface or "tread" of the tyres is turned to the exact form required.

Steel set-screws entered from the inside of the rim are used as a further means of securing the tyre to the rim of the wheel. The *balance weights* shown in fig. 17 are provided with the object of

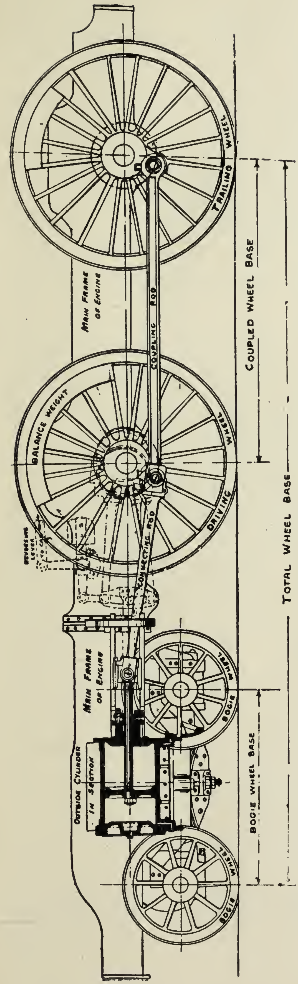


Fig. 17.—General Arrangement of Wheels, Cylinder and Motion for a Four-Wheels Coupled outside Cylinder Passenger Locomotive.

(Left hand side of engine.)

ensuring the even wear of tyres and the engine generally. The action of the reciprocating parts (*i.e.* pistons with rods, etc.) and the revolving parts (wheels, cranks and rods) of the engine is such as to cause a very irregular motion at any but a slow speed, and therefore the weights are there to counteract this effect. The driving wheels have larger balance weights because of the cranks and connecting rods, whereas in the other coupled wheels only half the coupling rod has to be balanced beside the crank and pin. The general steadiness in running and degree of oscillation depend on the accurate balancing of the engine.

The wheels are forced on to the axles by means of hydraulic presses, and keyways are cut, half in the axle and half in the wheel, and steel keys driven in. The crank pins are pressed into the wheels by hydraulic presses. The crank axles used for inside cylinders are either "built up" of separate parts or cast in one piece. They are invariably of steel (fig. 18).

The bogie truck, which carries the leading end of the engine,[1] is a separate carriage altogether, and is free to move independently of the main portion of the locomotive. It is held in place by means of a large central "pin" known as the bogie pin. This is fixed to the main frame of the engine at its upper extremity, whilst at the lower end it passes through a casting which forms the central portion of the bogie between the frames. This casting is riveted to the frames of the bogie, and it is planed at the top to receive a "cross-slide." The latter is planed both top and bottom, and is bored out for the reception of the bogie pin. The cross-slide is kept in position by controlling springs, and outside the frames of the bogie other springs placed in an inverted position are provided to take the weight.

The bogie pin is hollow, and through its centre another pin passes, and this is secured at the bottom by a nut and washer to prevent any likelihood of the bogie becoming disconnected from the engine (see fig. 19).

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[1] In tank engines the bogie is very often placed at the trailing end, and in a few cases both ends of the locomotive are supported upon bogies.

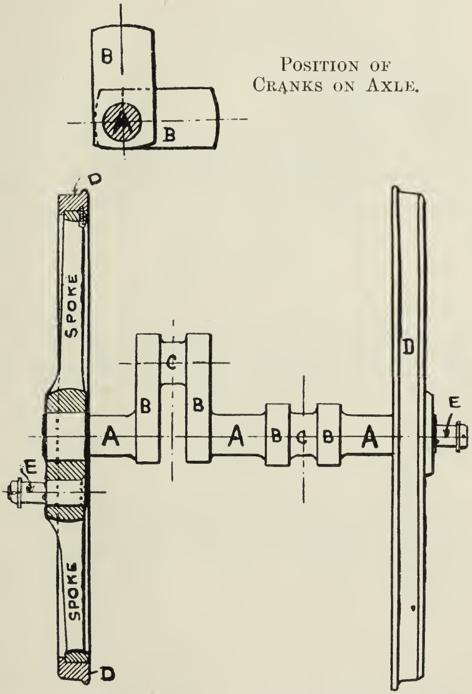
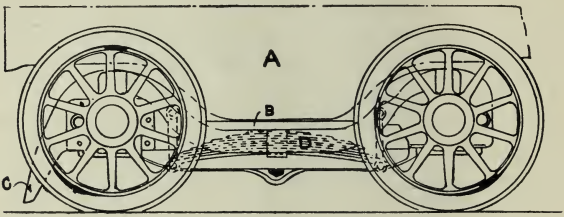

POSITION OF CRANKS ON AXLE.

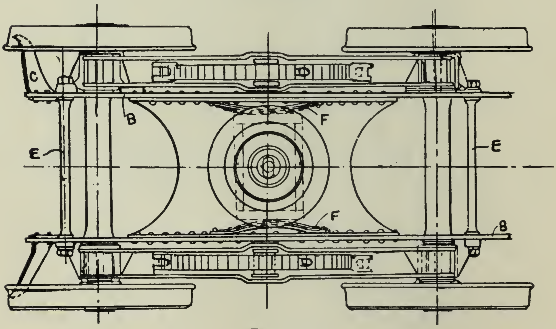
Fig. 18.—CRANK AXLE AND WHEELS FOR AN INSIDE LOCOMOTIVE.

A Axle.
B Crank Webs.
C Connecting Rod Crank Pins.
D Tyre.
E Coupling Rod Crank Pins.

When a locomotive fitted with a bogie truck strikes a curve, the frame partially revolves round the pin, and the cross-slide also moves in a transverse direction. When the curve has been traversed and the straight road is regained, the controlling spring referred to (which has been compressed whilst running round the curve on one side of the truck)



Elevation.



Plan.

Fig. 19.—A Four-wheeled Bogie Truck.

A	Main Frame of Engine.	**D**	Main Inverted Springs.
B	Frame of Bogie.	**E**	Stay Bars.
C	Guard Irons.	**F**	Controlling Springs.

resumes its normal position, and in so doing brings the truck back into its place.

The majority of locomotives intended for fast service are fitted with bogie trucks nowadays; indeed it would not be going too far to say that the practice is universal, and is undoubtedly the best plan for carrying the leading end of an engine. Not only does it greatly facilitate passing round curves and through switches, but it also assists the designer by making it easier to generally distribute the weight of the engine over a greater length and so to avoid excessive weight at any one point. The wheels and axles of a locomotive are connected to the main frames of the engine by means of springs, so that shocks and concussions may be lessened and the various parts of the engine protected from injury, through being unduly subjected to the rough treatment which they would meet with unless the springs were provided. The two most usual patterns used are those known as "laminated" or "plate" springs, and "coil" springs. The connecting and coupling rods are made of steel and are secured to the crank-pins by means of bolts, cotters and taper pins. In every case that portion of the rod end which is in actual contact with the crank-pin is made of gun-metal or similar material, but is spoken of as the connecting rod or coupling rod "brass."

Locomotives intended for long distance traffic are fitted with "tenders." These vehicles are for the conveyance of coal and water for supplying the engine *en route*, and thus rendering it unnecessary to stop in order to replenish the stock of either commodity. On some railways water is taken into the tender whilst the train is in motion. Water troughs are laid between the rails, and the tender is fitted with apparatus for taking up water at any speed at which the engine may be running. The apparatus consists of a hinged scoop, which can be let down so that the mouth is below the water in the trough and facing the direction in which the train is moving. The fact of the scoop being forced through the water in this way causes a supply of the latter to run upwards into the tender at great velocity, without the aid of pumps or other mechanical means.

The majority of tenders are run upon six wheels, but on many railways, notably those where water troughs are not used—"double bogie" (*i.e.* eight-wheel tenders on two separate bogie trucks) are employed. The water in the tender is conveyed by means of pipes to the injectors, which deliver it to the boiler. These injectors are of various patterns, and their action is brought about by utilising a jet of steam and bringing it in contact with the flow of water, so that the steam is condensed, and its velocity being imparted to the water, enables the combined steam and water to enter the boiler. During recent years a new pattern of injector has been introduced worked by exhaust steam, thus utilising steam which would otherwise go to waste.

Both at the front of the engine and at the back of the tender, spring buffers and screw-coupling gear is provided. The buffer beams are secured to the engine and tender frames by means of angle plates. One of the most important matters which bear upon locomotive construction is the question of brake power. Years ago reliance was placed entirely upon hand brakes, but nowadays it is compulsory for all passenger trains to be fitted with "continuous" brakes.

The two principal automatic brakes are the "Westinghouse compressed air" and the "automatic vacuum" brake. Both systems are extensively employed, and it would be difficult to decide as to which of the two is in reality possessed of the greater efficiency.

In the Westinghouse brake the engine is provided with a pump which supplies air at a pressure of 75 to 80 lb. per sq. in. to reservoirs beneath the engine and also under the carriages. These reservoirs are connected by a pipe extending throughout the train, and which pipe is connected together between each of the carriages and the engine tender by flexible hose pipes. When the pressure is released from the train pipe by the driver operating a small handle in the cab, the reservoir and the train pipe are automatically cut off from one another, and the former is placed in communication with the cylinder, the piston in which is forced outwards and the brake applied.

The vacuum brake is applied by admitting air into the train pipe, which air enters the cylinder below the piston. The admission of air to the train pipe automatically cuts it off from the reservoir, and also from that portion of the cylinder above the piston which is forced upwards by atmospheric pressure, and this movement causes the brake blocks to be brought in contact with the wheels.

The brakes are applied by means of blocks which are made to bear upon the tyres of the coupled wheels of the engine and all the wheels of the tender. In locomotives having only one pair of driving wheels the small "trailing" wheels are also braked. The blocks referred to are attached to "hangers," which are in turn suspended from the main frame of the engine at the upper end, whilst at the lower end they are connected to cross-beams which are connected by means of a system of rods to the mechanism by which the brake is operated.

Many engines are fitted with steam brakes, and all have hand-brake power in addition to those which are automatically applied.

It is necessary to provide locomotives with "sanding gear." In wet or frosty weather, when the rails are in a wet or greasy condition, the tendency is to cause the driving wheels to "slip" without imparting motion to the engine. If sand is deposited in front of the driving wheels they will then be assisted to obtain the necessary "grip" of the rail, and so the engine will move forward or backward as the case may be. Sand boxes are provided on either side of the locomotive, and pipes connected to the bottom are brought down to within an inch or so above the rail.

The necessary gear for working the valve which allows the sand to escape from the box down the pipe is worked from the cab. Steam sanding gear is largely used on modern engines. The advantage of this is that it deposits the sand right under the tread of the tyre at the point of contact between the wheel and the rail under all circumstances, whereas in the ordinary apparatus, where the sand falls down the pipe by gravity and without any propelling force of a mechanical nature, it is often blown away by the wind before it reaches the rail and thus the desired effect is lost. Compressed air is sometimes used for driving sand under the wheels, but steam is much more frequently the agent employed. Every working part of a locomotive has of course to be well lubricated. Oil cups and syphons are attached to the various parts so as to be easily accessible with the aid of oil cans, fitted with long spouts. Much of the lubrication of the engine is done by means of "sight feed lubricators" fixed in the driver's cab. The use of these is found to be very convenient, as the passage of the oil may be watched in the cab instead of its being necessary to go round the engine whilst running to ascertain if the oil cups are working properly. A glass tube filled with condensed water forms part of the cab fittings, and the oil has to pass through this tube on its way to the pipe which leads to the valve chest or cylinders or elsewhere. The oil is propelled by a jet of steam in this method of oiling.

CHAPTER III

MODERN LOCOMOTIVE TYPES

HAVING now completed our brief study of the locomotive from a constructional point of view, it will be interesting to turn our attention to the completed machine in some of its numerous forms, and inquire into the reasons for the many differences which exist, not only between the arrangement and general appearance of the engines used upon railways distinct from one another, but also between those to be seen in everyday working upon the same railway system.

These types might be divided and subdivided almost indefinitely, but in the interests of space it will be necessary to confine the matter to a review of the better known classes of engine, such as are employed for working the ordinary traffic on the majority of the main lines of this country.

The principal feature by which one design of locomotive may be distinguished from another is the number and position of the wheels, and, to facilitate the identification of locomotive types without having

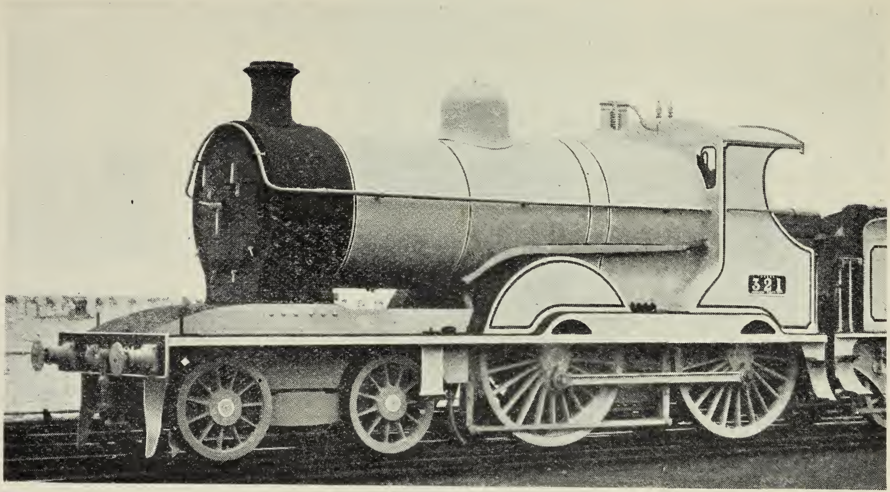
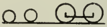
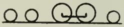
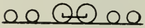
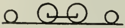
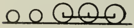
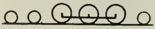
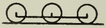
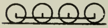
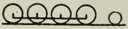
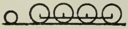


Fig. 20.—Four-coupled 4-4-0 type Express Locomotive with Coned Boiler for the Great Southern and Western Railway of Ireland.

recourse to the lengthy and tiresome method of describing the wheel arrangement in full, a system of notation has been adopted whereby the class to which a locomotive belongs can be ascertained at a glance or described verbally with the minimum of trouble. This is done by simply referring, with the aid of numbers, to the wheels as they are placed under the engine, the leading wheels first, then the coupled wheels, and lastly the trailing wheels. When a coupled axle leads, or is the last to be employed, the figure 0 is added to denote the fact; thus, instead of saying, or writing, four wheels coupled bogie locomotive, it is only necessary to use the formula 4–4–0, *i.e.* four bogie wheels leading, then four coupled wheels with no other wheels behind them. The following table will further explain the use of the method.

	Four-coupled bogie	4–4–0
	Atlantic	4–4–2
	Four-coupled double bogie, or "double-ender"	4–4–4
	Four-coupled double-ender	2–4–2
	Six-coupled bogie	4–6–0
	Pacific	4–6–2
	Six-coupled	0–6–0
	Eight-coupled	0–8–0
	Eight-coupled, radial	0–8–2
	Consolidation	2–8–0

Of course innumerable other combinations could be given, but the few selected above will suffice to illustrate the principle upon which the system of locomotive classification now generally adopted in this country is based. For working passenger trains engines are employed having larger wheels than when goods traffic has to be dealt with. No doubt readers have observed this for themselves, and have also noticed that passenger locomotives have as a rule either one pair of driving wheels or two pairs coupled together, whilst "goods" engines have three pairs coupled and in some cases four pairs, all of the same diameter and much smaller than that of the passenger engines.

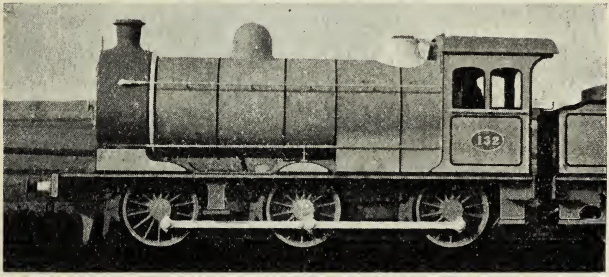


Fig. 21.—Six-coupled 0–6–0 type Locomotive, North-Eastern Railway.

It will be apparent to all that the *smaller* the diameter of the wheels the more quickly are the revolutions completed at any given speed, and fresh power can be more frequently applied by the cylinders, but that the *larger* the diameter of the wheels the easier it is to attain high speeds once the initial effort of starting has been overcome.

Now, goods trains are usually very heavy, and the speed at which they are hauled is moderate, so that small wheels are better adapted to this class of traffic. By coupling the wheels together the power exerted by the cylinders is communicated to *all the wheels at once*, through the medium of the coupling rods, instead of to only one pair or two pairs as the case may be. The larger the number of coupled wheels the better the "grip" which the engine gets on the rail; or, to put it in another way, the greater the amount of adhesive force which is exerted. Every wheel so coupled is virtually a driving wheel, and *directly assists* to propel the engine, whereas uncoupled wheels have to be pulled or pushed along according to whether they are behind or in front of the driving pair which obtains direct motion by means of the connecting rods. The weight of the engine itself provides adhesion, and this weight spread over three or four pairs of coupled wheels naturally has the effect of increasing the hauling capacity of the engine, but the speed capabilities are curtailed owing to the smallness of the wheels. Passenger trains are much lighter than goods trains, so that engines having fewer coupled wheels but of greater diameter are needed. The effort of starting away from a state of rest is not so easily overcome, but once the train is "under way" the engine will run faster because of the fewer revolutions which the wheel has to make to attain a high rate of speed, and the consequently slower movements of the piston and other reciprocating and rotating parts by means of which motion is communicated to the wheels.

Under modern conditions it is almost imperative

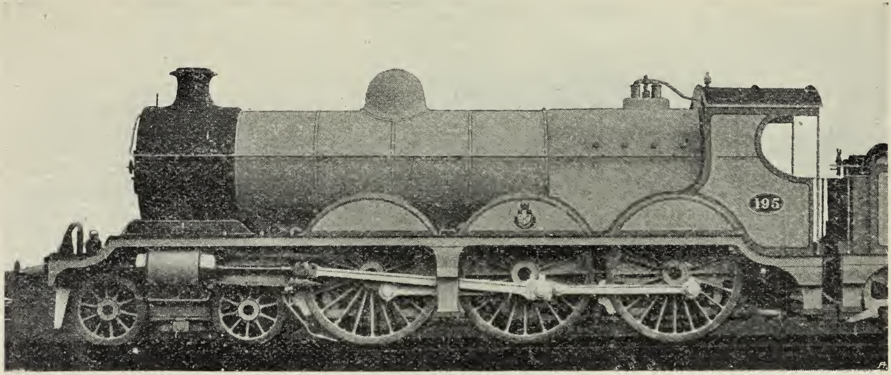


Fig. 22.—4-6-0 type Express Locomotive, Great Central Railway.

that at least two pairs of wheels should be coupled together in passenger locomotives. The use of "single" locomotives (*i.e.* those with only one large pair of wheels) is being slowly abandoned, as train weights are such nowadays as to render it necessary to employ engines capable of starting away more quickly, and running up inclines without losing speed to such a degree as often happens when uncoupled engines are used. With moderate train loads the "single" locomotive is unrivalled for high speed, the absence of the coupling rods being all in favour of exceptional prowess in that direction, but the type cannot be relied upon under the varying conditions which govern railway working; and further, windy and wet weather (which interferes in a very marked degree with the work performed by all classes of engines) is more detrimental to single driving engines than the other types, for the reason that the former have the least adhesion of any, and

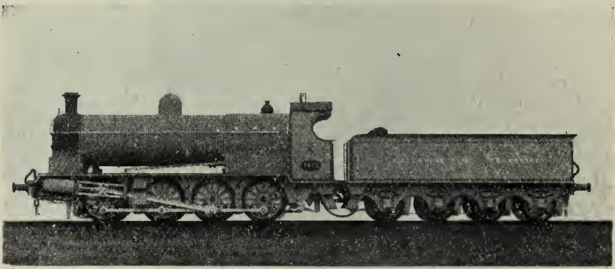


Fig. 23.—Eight-coupled 4-Cylinder Compound Goods Engine, 0–8–0 type, Lancashire and Yorkshire Railway.

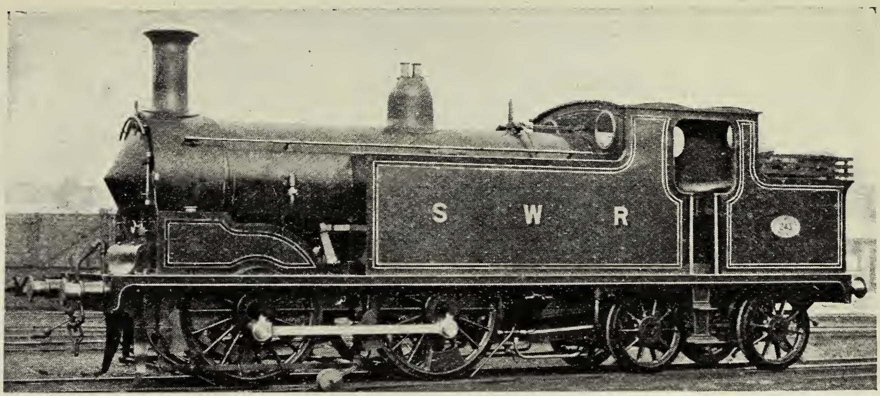


Fig. 24.—Bogie Tank Passenger Locomotive, 0-4-4 type, London and South-Western Railway.

therefore are very much hindered by the slipping of the driving wheels, which is a prolific cause of loss of power, and consequently headway is retarded.

The most general wheel arrangement for passenger engines is that in which two pairs are coupled together and are preceded by a four-wheeled bogie truck. Engines of this description used to be known as belonging to the "four-coupled bogie" class, but are now called 4–4–0 type engines, and either inside or outside cylinders may be employed with equal facility.

There being only two pairs of wheels coupled, the engine can be made to run at almost any desirable speed if not overloaded, and yet it possesses sufficient adhesion to allow of its being able under all ordinary circumstances to start away with a good load and to traverse gradients without losing too much of its speed.

Four-coupled engines have been known to run even faster on the level than a single engine under precisely similar conditions; and *vice versa*, the latter type have on occasions demonstrated their ability to haul equally heavy and sometimes heavier loads than the coupled engine over the same road. Much depends on the condition of the engine itself at the time and the way it is handled, all other conditions being equal. The writer recently conducted some experiments on locomotives of various types, and recorded on two occasions results which were entirely opposed to what recognised theories would have suggested, and on other occasions noted precisely the reverse; but in designing locomotives for specified classes of work it is customary and safe to ignore these occasional happenings and proceed on lines which are firmly established.

Upon some railways passenger engines are being introduced having six-coupled wheels and a leading truck, 4–6–0 type. This design is adaptable to circumstances involving *both* requirements, viz. power *and* speed. The extra coupling rods give greater adhesive power, whilst the diameter of the wheels is kept about the same as in the four-coupled design. For working heavy and fast passenger trains over hilly routes the six-coupled express engine is perhaps the best which can be employed. On other lines "Atlantic" 4–4–2 type engines have come into favour. These have a bogie truck leading, then four coupled wheels, and behind them a small pair of trailing wheels. The advantage claimed for this design is that as both pairs of coupled wheels are in

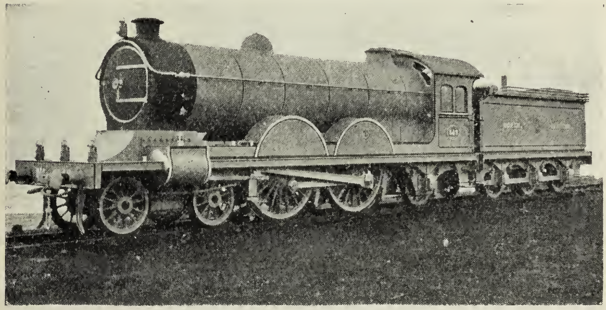


Fig. 25.—"ATLANTIC" OR 4–4–2 TYPE SIMPLE EXPRESS LOCOMOTIVE, NORTH-EASTERN RAILWAY.

front of the fire box an almost unlimited space is available for the development of the fire box itself. Goods engines with eight-coupled wheels are in use on several railways, some having outside and some inside cylinders. The hauling power of this class of engine is very great, and trains made up of sixty loaded trucks and weighing upon the average between 700 and 800 tons, and at times considerably more, are drawn with ease by them. On the London and North-Western Railway large numbers of eight-coupled compound locomotives have been built. Some of these have three and others four cylinders. In each case the high-pressure cylinders are outside the frames and the low-pressure inside, and all drive the same axle. The three-cylinder locomotives are being converted into two-cylinder simple engines.

It is usual on some railways to make the driving wheels or the third pair of wheels of these eight-coupled engines without flanges to facilitate rounding curves. The long coupled wheel base presents a rigid resistance to the movements of the engine when passing round curves, and this is partially relieved in the manner referred to.

Very few engines which are intended entirely for goods traffic are fitted with bogie wheels in this country. The Great Western Railway have a few, and the London and North-Western and Caledonian Railways have a "fast goods" design in which six-coupled wheels are provided, and also a leading truck.

Inside cylinders are still very popular in Great Britain, but the outside position is being largely

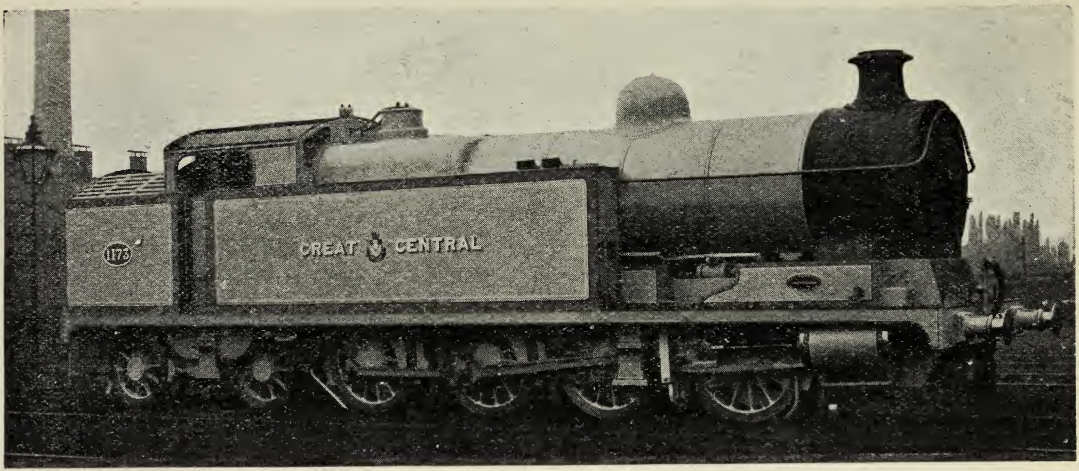


Fig. 26.—Eight-coupled Bogie Tank Engine, 0-8-4 type, Great Central Railway.

resorted to on many lines. The advantages claimed for the respective methods are briefly as follows:—

Inside cylinders.	*Outside cylinders.*
(1) The cylinders are protected from atmospheric conditions and retain their heat better.	(1) Access to working parts rendered easier.
(2) Motion of engine protected from dust and wet.	(2) No crank axle (which is liable to break).
(3) Steadier running engine.	(3) Direct driving on to the wheels themselves.
(4) General neatness of appearance.	

Both methods have undoubted advantages, and both, it is needless to add, have their ardent advocates. Many engines have a combination of both inside and outside cylinders—the North-Western compounds and the South-Western four-cylinder engines, for instance. The Great Central, North-Eastern, Midland, Glasgow and South-Western, Great Northern, Great Western, and Lancashire and Yorkshire Railways, also possess locomotives with three or more cylinders.

The "tank" engine designs are innumerable. Practically every railway company possesses one or two separate classes of these engines. Some have a great many more. Perhaps the most commonly used type is that having four wheels coupled in front and a trailing bogie under the cab, but there are many ten-wheel tank engines now running with a leading truck, four coupled wheels, and a trailing pair behind the fire box. The principal advantage of ‘tank” locomotives is their handiness. They run equally well in either direction, and therefore do not need turning at the end of every journey. They carry the coal and water on the same framework as the engine and boiler, and are an all-round compact and convenient pattern of engine for working suburban and shorter distance traffic, and for such are largely employed by all railway companies.

As giving an approximate idea of the principal dimensions usual in passenger engines of the four-coupled bogie type, the following are thoroughly representative for an up-to-date British locomotive.

Cylinders, 19 to 20 in. dia. × 26 in. stroke.
Coupled wheels, 6 ft. 6 in. to 7 ft. dia.
Bogie wheels, 3 ft. 6 in. to 4 ft.
Boiler diameter, 4 ft. 9 in. to 5 ft. 6 in.
Length of barrel, 11 ft. to 12 ft.
No. of tubes, 250 to 300, 1⅝in. to 2 in. diameter.
Centre line of boiler above rail, 8 ft. to 8 ft. 6 in.
Rail to top of chimney, 13 ft. 4 in.

Heating surface (tubes) . .	1540	sq. ft.
„ (fire box) . .	125	„
Total .	1665	„

Carrying capacity of tender, 5½ tons coal and 4000 gallons water.

Total weight of engine and tender in working order, 95 to 100 tons.

The wheels of six-coupled goods engines vary between about 4 ft. 9 in. to 5 ft. in diameter. Eight-coupled goods engines usually have wheels about 4 ft. 3 in. to 4 ft. 9 in. in diameter, six-coupled bogie passenger engines 6 ft. to 6 ft. 6 in., and passenger tank engines from 5 ft. 6 in. to 6 ft. diameter. The London, Brighton, and South Coast Railway have a number of these engines with 6 ft. 9 in. wheels, the largest in this country for this type of engine.

The various types of engines and the class of traffic for which they are specially adapted may be summed up as follows :—

(1) "Single driving" engines.	Fast, and moderately weighted passenger trains.
(2) Four wheels coupled, 6 ft. 6 in. to 7 ft.	Heavier passenger trains, also booked to run at high speeds.
(3) Four wheels coupled, 5 ft. 6 in. to 6 ft.	Passenger trains on hilly stretches, and also "fish" specials and excursion traffic.
(4) Six-coupled bogie engines.	Fast heavy passenger trains on very hilly sections, especially where traffic is competitive and four-coupled engines have to be run in duplicate to keep time.
(5) "Atlantic" type.	Same as No. 2.

(6) Six-coupled type with bogie, 5 ft. 6 in. to 6 ft.	Same as No. 3 as regards class of traffic, but may be used on heavier work.
(7) Six-coupled, without other wheels.	Goods trains up to about 500 or 600 tons weight.
(8) Eight wheels coupled, no other wheels.	The heaviest class of goods trains, weighing up to 800 or 900 tons.
(9) Tank engines.	Suburban and shorter distance main line traffic. These engines are, however, at times called upon to do all kinds of main line work.

CHAPTER IV.

A LOCOMOTIVE CATECHISM IN BRIEF.

Q. = *Question.* A. = Answer.

Q. How many parts does a locomotive boiler consist of?

A. Four: (1) the inner fire box, (2) the outer fire box, (3) the barrel, and (4) the smoke box.

Q. What are the functions of each part?

A. (1) contains the fire itself, (2) forms a protective shell and water space, (3) contains the tubes, etc., and (4) is a chamber in which the gases are collected after passing through tubes and which are carried away up the chimney by the action of the blast. The steam pipes to the steam chest, etc. are also fixed in the smoke box.

Q. Why are tubes provided?

A. To form heating surface with which the water in the boiler is brought in contact and is converted into steam, and at the same time provide a means of communication between the fire box, through which the gases, air currents, etc., pass.

Q. What material is used for tubes?

A. Either copper, brass, iron, or steel.

Q. What material is used for inner and outer fire boxes and boiler barrels?

A. Inner fire boxes generally copper; outer shells iron or steel; boiler barrels iron or steel.

Q. How are the fire boxes connected together?

A. By means of screwed stay-bolts sides, front and back, and by girder or "direct" stays on top. The "foundation ring" also helps to secure them together.

Q. What is the object for which the dome is provided?

A. To act as a reservoir for steam above the water-level of the boiler.

Q. Why above the water-level?

A. Because "dry" steam, or steam unmixed with water, does better work in the cylinders—exerts more power.

Q. What else is the dome for?

A. It contains the regulator valve, which governs the admission of steam to the cylinder supply pipe.

Q. What other fixtures are there on the boiler?

A. The safety-valves and whistle.

Q. What are their functions?

A. The safety-valves to relieve the pressure in the boiler when it becomes too great; the whistle to give audible warning of approach, and for signalling.

Q. After the steam has left the dome, the regulator being opened, what does it do?

A. Passes along the supply pipe to the steam chests.

Q. And what next?

A. Enters the cylinder through one of the ports.

Q. And then?

A. Forces the piston before it in one direction or the other according to which side of the piston it has been admitted.

Q. What effect does this have?

A. It moves the piston rod and cross-head (along with the piston), and also the connecting rods which cause the driving wheels to revolve and the engine to go forward.

Q. But how if it is desired the engine shall go backward?

A. Then the engine must be " reversed."

Q. How is this done?

A. By means of the link motion.

Q. What is the link motion?

A. A mechanical means of reversing the engine, and also altering the travel of the slide valve according to the requirements of the driver. More steam or less steam may be admitted to the cylinders as desired by raising or lowering the link by means of the reversing wheel in the cab, and the engine may be made to travel in either direction at will by the same method. If the "expansion link" is lowered to the utmost extent the motion of the valve is governed by the forward eccentric and (if raised as much as possible) by the backward eccentric, whilst the central position is mid-gear and the engine will not move at all, as no adequate supply of steam can be admitted to the cylinders, the valves having insufficient travel.

Q. What is meant by piston stroke?

A. The distance travelled by the piston from one end of the cylinder to the other.

Q. What positions do the cylinders occupy?

A. They are either outside or between the frames, and generally immediately adjacent to the smoke box.

Q. How is motion communicated to the wheels when outside cylinders are used?

A. By connecting rods acting on crank pins in the wheels themselves.

Q. When inside cylinders are used, how is it managed?

A. The driving wheel axle is provided with two cranks.

Q. What angles are they set at with relation to one another?

A. Usually 90° (right angles).

Q. Why?

A. Because with this arrangement when one piston is at the end of the stroke the other is under the full influence of the steam and working to its greatest advantage.

Q. What are "compound locomotives"?

A. Those in which the cylinders are of unequal diameters, and in which the steam which has been supplied from the boiler is used *twice* before being ejected into the atmosphere.

Q. What are these cylinders called?

A. The smaller ones are called high-pressure or the "first" cylinders, and the larger ones the low-pressure or "second" cylinders.

Q. What is the advantage claimed for this method?

A. That by using the steam twice over, first in the high-pressure cylinder, and then (by reason of expansion) in the low-pressure cylinder, a great saving in steam and fuel is obtained.

Q. Why are larger wheels used on engines employed in hauling passenger trains than on those which deal with goods traffic?

A. Because higher speed is required than would be possible with the small wheels used on goods engines, which could never be got to revolve fast enough to give the required speed.

Q. Goods engines have three pairs and sometimes four pairs of wheels coupled. Why is this?

A. The greater number of wheels coupled the more the adhesion, and as it is required to start away with heavy loads and keep them moving once they are started whether the road is level or hilly, this matter of adhesion is all-important, as it means a "grip" on the rail when the resistance of the train is at its greatest.

Q. Why not have ten or twelve wheels coupled?

A. Because the coupled wheel or "rigid" wheel base would be very long, and would interfere with the movements of the engine when rounding curves.

Q. Are such engines never employed?

A. Not in this country up to the present, although a locomotive has been built with ten coupled wheels placed closely together.

Q. Why are tenders provided on some engines and not on others?

A. Those engines which have to run long distances without stopping are supplied with tenders. Those intended for local and shorter distance work are not.

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